UNIVERSITY OF BIRMINGHAM

Research internship projects in the College of Engineering and Physical Sciences

The College of Engineering and Physical Sciences at the University of Birmingham is one of the largest groupings in Europe, bringing together physical sciences and engineering into one coherent college. Home to nine academic schools, the College affords students, staff and alumni access to learning and career development opportunities which few educational institutions can match.

Much of our activity involves collaboration with multiple stakeholders – individuals, public bodies and private companies. The College focuses on fostering strong links with strategically important partners and stakeholders. From research collaborations and education networks to business engagement and alumni communications, the College has widened its reach and influence.

The College is home to many research groups that sit within and across academic schools that also contribute to three overarching themes spanning the breadth of the College. They are:

- Science Frontiers: fundamental breakthroughs in our understanding of the way nature works.
- Advanced Manufacturing: driving industry forward; delivering the edge in the global competition through innovation.
- Resilience, Energy and Sustainability: tackling the challenges of future generations now.

On behalf of the College of Engineering and Physical Sciences, I am delighted to present a number of research internship opportunities which we are able to make available to outstanding students over the summer period of 2016. Each project is being made available by some our leading research groups in the School of Physics and Astronomy and in the School of Computer Science. For each available project, brief details have been provided, together with a list of key references and contact details for the supervisor.

I hope you find the list of project stimulating. If you would like to pursue any of the projects listed, in the first instance, please send a brief expression of interest outlining your reasons behind wanting to undertake a research internship in our College and your specific interest in the project selected, to the Director of the College of Engineering and Physical Sciences Graduate School, Dr Peter Hancox (pjh@cs.bham.ac.uk).

I look forward to welcoming a cohort of research interns in the forthcoming summer months.

Professor Jon Rowe
Director of Research and Knowledge Transfer
College of Engineering and Physical Sciences
University of Birmingham

Project:	**CE1: Measuring soil water characteristics curves to assess the water potential of soils collected from site**
Supervisors:	**Dr N. Metje (n.metje@bham.ac.uk)**
	Dr G Curioni (g.curioni@bham.ac.uk)
School:	**Civil Engineering**

Buried archaeological features can be detected by proxy as crops respond differently to the local change in subsurface conditions. Where plants are rooted in or near to buried features, plants can grow at different rates than those in the surrounding area. At times when crops are under stress from low available water the differential growth can appear as a visual difference (e.g. increased or reduced greenness, and early or late flowering) resulting in markings known as crop marks.

Detection and mapping of archaeological features in the UK using aerial imagery is carried out over the summer months when soils are typically at their driest. The timing of these surveys is critical as crop marks may only appear for a few days when crop, climatic and geological conditions allow.

Soil Water Characteristic Curves (SWCC) can be used to determine the water content at which plants will become under stress, the Permanent Wilting Point (PWP), for different soil types. The full range of the SWCC can be empirically estimated from the PSD, though a laboratory dewpoint potentiameter can determine a range within the SWCC which includes the PWP (-1.5 MPa).

Existing data which maps the appearance of cropmarks caused by buried ditch features over time, along with water contents both inside and adjacent to the features has not been compared with laboratory determination of the SWCC.

Note, applications are beyond archaeological prospection and knowing the soil water characteristic curve for a soil will provide significant insight into the effects of water on geophysical surveys such as GPR and will provide an insight into the soil conditions.

This project aims to assess the likely appearance of crop marks in terms of the SWCC determined by laboratory testing of soils. The objectives include:

- Understand the principals of SWCC and PWP
- Develop a testing methodology to compare laboratory determined PWP and the appearance of crop marks from existing real world data
- Characterisation of soils from within and adjacent to buried features
- Determination of the water content at the PWP using a dewpoint potentiameter
- Comparison of the results against existing water content data to assess the correlation with crop mark appearance

References:

Evans, R. (1990) Crop patterns recorded on aerial photographs of England and Wales : their type, extent and agricultural implications. **Journal of Agricultural Science**, 115 (3): 369–382

Evans, R. and Jones, R.J.A. (1977) Crop Marks and Soils at Two Archaeological Sites in Britain. **Journal of Archaeological Science**, (4): 63–76

Jones, R.J.A. and Evans, R. (1975) Soil and Crop Marks in the recognition of Archaeological sites by Air Photography. **Council for British Archaeology: Aerial Reconnaisance for Archaeology**, Research R: 1 – 9

Thacker, V., Sreedeep, S., and Singh, D. (2005) Parameters affecting soil-water characterstic curves of fine-grained soils. **Geotech. Geoenviron. Eng.** 131 (4): 521-524

Project: **CE2: Signal Transmission through Soil**
Supervisors: **Dr N. Metje (n.metje@bham.ac.uk)**
Dr D Chapman (d.n.chapman@bham.ac.uk)
School: **Civil Engineering**

Asset owners are constantly thriving to improve their asset management in order to make it more efficient, thereby saving money and being more profitable to shareholders while serving their customers. The utility network is one of the most complex networks in the world with most of it invisible from the ground surface and thus it is unnoticed unless it fails in some manner. The monitoring of its condition is problematic due to the inaccessibility of large parts of the network (unless one excavates to the pipelines) and due to the fact that the ground covering the asset makes any signal transmission from the surface or to the surface challenging.

However, for a utility asset owner to be proactive in the management of its infrastructure, some knowledge of the condition of the asset and/or its contents is important. In an ideal world, a monitoring system, introduced into the utility/pipeline infrastructure, would warn of impeding failure. Existing systems broadly achieve this aim, but they lack accuracy due to the limitations of the technology involved.

In previous projects, the communication between wireless sensors through the ground, i.e. the signal transmission through soils has been identified as a key challenge. The distance a signal can travel depends on specific soil properties such as PSD, water content, permittivity and conductivity values for the soil as well as the frequency and power of the signal.

This project will focus on doing an extensive test programme using a VNA to determine the real and imaginary part of the soil's permittivity. This information will then form the input into the numerical models where a parametric study identifying the key soil parameters is to be performed.

References:

Metje, N., Chapman, D.N., Walton R., Sadeghioon, A.M., Ward. M. (2012). Real time condition monitoring of buried pipes. *Tunnelling and Underground Space Technology* 28, pp. 315-320.

Metje, N., Chapman, D.N., Cheneler, D., Ward, M., Thomas, A.M. (2011). Smart Pipes—Instrumented Water Pipes, Can This Be Made a Reality? Sensors 2011, Special Issue: Collaborative Sensors, 11. pp. 7455 – 7475, doi:10.3390/s110807455.

Project:	**CE3: Energy Harvesting using Temperature Gradient in Soil**
Supervisors:	**Dr N. Metje (n.metje@bham.ac.uk)**
	Dr Ali Sadeghioon (a.m.sadeghioon@bham.ac.uk)
School:	**Civil Engineering & Mechanical Engineering**

Asset owners are constantly thriving to improve their asset management in order to make it more efficient, thereby saving money and being more profitable to shareholders while serving their customers. The utility network is one of the most complex networks in the world with most of it invisible from the ground surface and thus it is unnoticed unless it fails in some manner. The monitoring of its condition is problematic due to the inaccessibility of large parts of the network (unless one excavates to the pipelines) and due to the fact that the ground covering the asset makes any signal transmission from the surface or to the surface challenging.

However, for a utility asset owner to be proactive in the management of its infrastructure, some knowledge of the condition of the asset and/or its contents is important. In an ideal world, a monitoring system, introduced into the utility/pipeline infrastructure, would warn of impeding failure. Existing systems broadly achieve this aim, but they lack accuracy due to the limitations of the technology involved.

Sensors have been developed to attach to buried pipes. However these require power. Pipes have a lifetime of over 100 years and for the sensors to be cost effective they should have a similar lifetime as excavation down to the sensors and regular replacement of batteries is not possible. Previous research has shown that the temperature gradient over 500m in the top 1m from the ground surface is sufficient to harvest energy which can then power the sensors. Therefore, this project focusses on reviewing existing temperature harvesting devices and the construction of a prototype energy harvester, which can be buried in a small-scale laboratory trial.

References:

Metje, N., Chapman, D.N., Walton R., Sadeghioon, A.M., Ward. M. (2012). Real time condition monitoring of buried pipes. *Tunnelling and Underground Space Technology* 28, pp. 315-320.

Metje, N., Chapman, D.N., Cheneler, D., Ward, M., Thomas, A.M. (2011). Smart Pipes—Instrumented Water Pipes, Can This Be Made a Reality? Sensors 2011, Special Issue: Collaborative Sensors, 11. pp. 7455 – 7475, doi:10.3390/s110807455.

Project: **CE4: Developing a Novel Rain Gauge for Use in Urban Environments**
Supervisor: **Dr S Sharifi (S.Sharifi@bham.ac.uk),**
Dr Nicole Metje (n.metje@bham.ac.uk)
School: **Civil Engineering**

The measurement of rainfall in urban environments is a crucial task, with the gathered results playing a key part in flood hazard mitigation, the monitoring and control of pollution, and water resource management. However, there has been a noted decline in the positioning of rain gauges in these environments, due to a combination of cost issues, and the difficulties of recording accurate data, due to the variable urban environment. These difficulties range from water running off of buildings, to vandalism, with the under catchment due to wind, being the largest contributor to errors. It is for these reasons that there is a need to study, develop and assess cheap and novel rain gauges suited to operate in urban environments.

This project is concerned with developing a new technique based on image recognition to estimate rainfall intensity and volume. A rainfall simulator will be built to generate synthetic rainfall, and a range of cameras and sensors will be used to capture the different attributes of rainfall. Image recognition techniques will be used to analyse the pictures and videos, and a numerical model will be built to model the rainfall based on inputs from the cameras and sensors.

Required Skills:
Photography, Image analysis, data analysis, High-level programming

References:
Nystuen, J. A. (1999), Performance of automatic rain gauges under different rainfall conditions, J. Atmos. Oceanic Technol., 16,1025–1043,

Duchon, C. E. (2008), Using vibrating-wire technology for precipitation measurements, in Precipitation: Advances in Measurement, Estimation and Prediction, edited by S. C. Michaelides, pp. 33–58, Springer, Berlin,

Stewart, R. D., Hut, R., Rupp, D. E., Gupta, H., &Selker, J. S. (2012).A resonating rainfall and evaporation recorder. Water Resources Research, 48(8).

Project: **CE5: Spacial optimization of Green Infrastructures in Urban Areas**
Supervisor: **Dr S Sharifi (**S.Sharifi@bham.ac.uk**),**
Dr Nicole Metje (n.metje@bham.ac.uk)
School: **Civil Engineering**

Addressing stormwater runoff and pollution challenges associated with urbanization is complex and relies on costly engineering, especially in highly-developed urban environments. Increasingly, distributed management of stormwater runoff using Green infrastructure (GI) is emerging as a multi-benefit solution that can address both stormwater quality and quantity concerns. Consistent with this trend, many local governments are required to develop and implement watershed-scale green infrastructure plans to cost effectively achieve quantitative water quality improvements and provide reasonable assurance that GI will achieve the desired load reductions. However, despite the recognized effectiveness of GIs, their interconnection and overall effect on the whole watershed in terms of stormwater quality and quantity is not well understood.

The goal of this project is to combine hydrologic and water quality modelling with a multi objective optimization algorithm, to perform a cost-benefit analysis of stormwater runoff control, in order to identify the optimal type and location of GIs for an urban setting. The project will attempt to answer the following questions:

1- Where could green infrastructure be used to reduce flows and pollutant loads?
2- What are the most cost-effective locations?
3- What flow and load reductions could we expect to see over decades as green infrastructure is implemented?

Required Skills:
Data analysis, High-level programming, Optimization, GIS, Hydrologic modelling

References:
Deb, K., Pratap, A., Agarwal, S. and Meyarivan, T. (2002) A fast and elitist multiobjective genetic algorithm: NSGA-II. *IEEE Transactions on Evolutionary Computation*, IEEE, 6 (2): 182-197.

Lai, F., Shoemaker, L. and Cheng, M.S. (2005) Decision support framework for placement of BMPs in urban watersheds. U.S. Environmental Protection Agency Science Forum.

Lai, D., L. Shoemaker, T. Dai, J. Zhen and J. Riverson (2007) SUSTAIN - A BMP Process and Placement Tool for Urban Watersheds, Proc. Engineering Conference International on Modeling, Arcata, CA.

Perez-Pedini, C., Limbrunner, J.F. and Vogel, R.M. (2005) Optimal Location of Infiltration-Based Best Management Practices for Storm Water Management, Journal of Water Resources Planning and Management, ASCE, 131(6):441-448.

Project: **CS1: Synthesising Formally Verified Controllers**
Supervisor: **David Parker (d.a.parker@cs.bham.ac.uk)**
School: **Computer Science**

Formal verification is an approach for checking the correctness of a computerised system during its design phase. There is increasing interest in formally verifying *quantitative* properties such as performance and reliability. For example: "with probability at least 0.999, the robot always completes its mission within 10 minutes of being deployed". These properties are expressed formally in temporal logic and can be checked against a mathematical model of the system to be verified. Verification software, such as the widely used PRISM tool, developed at the University of Birmingham, can be used to automatically perform these checks. A closely related technique is *controller synthesis*, which aims to automatically generate controllers (e.g. for a robot) that guarantee such quantitative properties will hold.

This project will enhance the support for controller synthesis techniques in the PRISM verification tool. There are multiple challenges to tackle, including how to efficiently extract controllers once they have been generated and how to present these controllers to a user of the tool.

Required skills
Basic knowledge of logic and automata, good programming skills for developing prototype tools, ideally in Java.

References:
G. Norman and D. Parker. *Quantitative Verification: Formal Guarantees for Timeliness, Reliability and Performance*. A report by the London Mathematical Society and the Smith Institute. Edited by Robert Leese and Tom Melham. 2014. http://www.cs.bham.ac.uk/~parkerdx/bibitem.php?key=NP14

M. Kwiatkowska and D. Parker. *Automated Verification and Strategy Synthesis for Probabilistic Systems*. In Proc. 11th International Symposium on Automated Technology for Verification and Analysis (ATVA'13), volume 8172 of LNCS, pages 5-22, Springer. October 2013. http://www.cs.bham.ac.uk/~parkerdx/bibitem.php?key=KP13

M. Kwiatkowska, G. Norman and D. Parker. PRISM 4.0: Verification of Probabilistic Real-time Systems. In *Proc. 23rd International Conference on Computer Aided Verification (CAV'11)*, volume 6806 of LNCS, pages 585-591, Springer. 2011. http://www.prismmodelchecker.org/bibitem.php?key=KNP11

PRISM http://www.prismmodelchecker.org/

Project: **CS2: Static Power Consumption Side Channels**
Supervisor: **Dr David Oswald (d.f.oswald@cs.bham.ac.uk)**
School: **Computer Science**

Background: Side-channel Attacks are a power technique to break mathematically secure cryptography (e.g. the AES or RSA) by measuring physical signals, for example, the power consumption of an embedded device. Then, the cryptographic secrets can be extracted using statistical methods like Differential Power Analysis (DPA).

State-of-the-art: Currently, side-channel attacks are most often carried out using the so-called dynamic or switching power consumption that is measured with an oscilloscope. Another form of side-channel leakage, the static power consumption, has only been studied to a limited extent [1].

Aims: The goal of this project is to analyse the static leakage of one or several modern microcontroller(s) in detail. The first step is to adapt the existing measurement setup to static power measurements, integrating a digital multimeter connected to the measurement workstation. Then, measurements are acquired and finally processed and evaluated. An interesting side aspect of the project would be to see if the instruction sequence executed by the device also leaks through the static power side channel (similar to [2]).

Required Skills:

- Programming knowledge in Python and/or C(++)
- Basic Linux command line skills
- Experience with microcontrollers and electronics would be a plus, but is not a must. The student will be especially supported in this regard.

References:

[1] Moradi, Amir. "Side-Channel Leakage through Static Power." http://www.ei.ruhr-uni-bochum.de/media/crypto/veroeffentlichungen/2014/07/08/StaticLeakageCHES14.pdf

[2] Strobel, Daehyun, et al. "Scandalee: a side-channel-based disassembler using local electromagnetic emanations." *Design, Automation & Test in Europe Conference & Exhibition (DATE), 2015*. IEEE, 2015.
http://www.ei.ruhr-uni-bochum.de/media/crypto/veroeffentlichungen/2015/03/05/SCANDALee_.pdf

Project: **CS3: Social media analytics using machine learning approaches**
Supervisors: **Dr Shuo Wang (s.wang@cs.bham.ac.uk)**
Prof. Xin Yao (x.yao@cs.bham.ac.uk)
School: **Computer Science**

Background: Social media (e.g. twitter, Facebook) is becoming a valuable source of timely information on the internet. It attracts a growing number of people, sharing, communicating, connecting and creating user-generated data. However, information is not knowledge. How to discover knowledge from such large amount of social media data becomes utterly important. For example, a company would like to make relevant product recommendations to people who have shown any type of interest. There is often little data for each specific individual collected offline (e.g. questionnaire). It will be a good idea to exploit the characteristics of social media and use its multi-dimensional, multi-source and multi-site data to aggregate information with sufficient statistics. Machine learning can play such a role, learning from and making predictions on data through pattern recognition and computational learning algorithms.

Challenges: Social media data differs from traditional data, because most of them are unstructured. With hundreds of millions of people spending hours on social media, it is a unique source of big data. Due to the large variety of platforms of producing social media data and the large amount of users, social media data is noisy, free-format, varying in length, and multimedia. Furthermore, the underlying patterns in social media data are drifting fast. For example, the hot online topic at the current moment can change hour-by-hour.

Aims: This project aims to tackle the learning challenges in twitter data, by developing advanced machine learning approaches. It is a genuine real-world data set collected from 2008 to 2011, containing 284 million following relationships, 3 million user profiles and 50 million tweets. Different learning algorithms will be considered and discussed to discover the interesting patterns in the data.

Methodologies*:* The student will look into the learning task of predicting the category that the tweet falls into, e.g. sports, food, etc. In practice, this can help a company to capture the current trend and recommend related products to users based on their online messages, so that a customised service can be provided. First, text mining techniques will be used to pre-process the social media data, in order to make it suitable for learning. Second, online learning approaches will be investigated and developed to learn data streams that may involve class evolution and concept drifts. Third, class imbalance and multi-class techniques will be explored to find interesting patterns in tweets.

References:
S. Wang, L. L. Minku, and X. Yao. Resampling-based ensemble methods for online class imbalance learning. *IEEE Transactions on Knowledge and Data Engineering*, 27(5):1356 – 1368, 2015.
Y. Sun, K. Tang, L. L. Minku, S. Wang, and X. Yao. Online ensemble learning of data streams with gradually evolved classes. *IEEE Transaction on Knowledge and Data Engineering*, (Accepted), 2016.
S. Wang and X. Yao. Multi-class imbalance problems: Analysis and potential solutions. *IEEE Transactions on Systems, Man and Cybernetics, Part B: Cybernetics*, 42(4):1119–1130, 2012.
L. L. Minku and X. Yao. DDD: A New Ensemble Approach for Dealing with Concept Drift. *IEEE Transactions on Knowledge and Data Engineering*, 24(4):619 – 633, 2012.

Project: **CS4: Browser-based goal reminder extension**
Supervisors: **Charlie Pinder (c.pinder@cs.bham.ac.uk)**
Bob Hendley (rjh@cs.bham.ac.uk)
Prof Russell Beale (rxb@cs.bham.ac.uk)
School: **Computer Science**

This project develops browser extension(s) for conducting experiments in subtle goal reminders during browsing sessions. Many behaviour-change approaches use goals to try and support their users to form new habits. However, it is not always possible to keep goals in mind while performing everyday tasks, and interrupting users to remind them about their goals can result in irritation.

We are instead exploring the use of subtle browser-based goal reminders, which will be delivered, configured and monitored via an extension. Users nominate a keyword to represent their goal, and the extension then subtly highlights every related word in all their browsing sessions. The extension needs to support configurable highlighting (users can alter their goal word lists, and disable highlighting when necessary) and user monitoring (so that we can conduct experiments on the efficacy of the approach).

The aim of the project is to create an experiment-ready extension (for at least one browser Chrome or Firefox), building on an existing Chrome prototype extension, and to carry out a pilot test of the system. If time permits, a larger-scale test with end-users will be carried out.

Required skills
Excellent programming skills in Javascript, ideally experience in developing browser extensions. PHP and PostgreSQL skills would also be helpful.

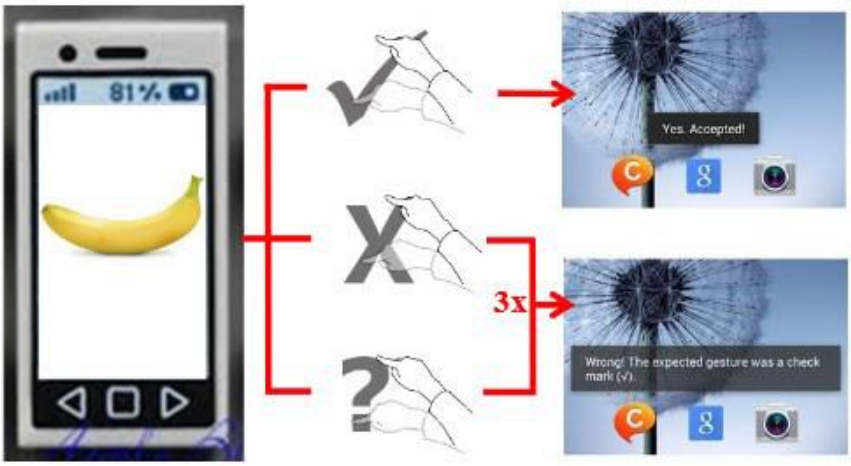
Training
Experimental design with human subjects.

References:
Aarts, H., Custers, R., and Veltkamp, M. Goal Priming and the Affective-Motivational Route to Nonconscious Goal Pursuit. *Social Cognition 26*, 5 (2008), 555–577.

Pinder, C., Vermeulen, J., Beale, R., and Hendley, R. Exploring Nonconscious Behaviour Change Interventions on Mobile Devices. MobileHCI'15 Adjunct, ACM Press (2015).

Project: **CS5: Personalised cognitive bias modification Android framework**
Supervisors: **Charlie Pinder (c.pinder@cs.bham.ac.uk)**
Bob Hendley (rjh@cs.bham.ac.uk)
Prof Russell Beale (rxb@cs.bham.ac.uk)
School: **Computer Science**

We are exploring the use of cognitive bias modification (CBM) techniques on mobile devices to support behaviour change. CBM techniques show promise in psychology as an attitude, affect and/or behaviour change technique, but have yet to be implemented or evaluated extensively on smartphones. We are particularly interested in the use of 'incidental' CBM, i.e. CBM training that is integrated into pre-existing user gestures such as unlocking their phone or browsing a gallery of pictures. We have completed a pilot (Pinder et al., 2016) exploring the use of gestures at unlock time to 'accept' images of healthy foods and 'reject' images of unhealthy foods.



Screenshots from our existing pilot application to require users to 'accept' healthy foods on unlocking their smartphone

The aim of this project is to build on the pilot and create a personalisable and configurable Android framework that allows users and/or researchers to build a series of CBM apps. Users and/or researchers should be able to use the framework to:

1. specify a series of items that they wish to pay more attention to (e.g. healthy foods) and a series of items they wish to pay less attention to (e.g. unhealthy foods).
2. specify when these prompts should be shown (e.g. on unlock; during website browsing; during photo browsing);
3. and/or specify which gestures should be used to 'accept' the items they wish to pay more attention to, and which gesture(s) should be used to 'reject' the items they wish to pay less attention to.

The framework should be integrated with an appropriate monitoring tool (e.g. Google Analytics). If time permits, the framework will be deployed on Google Play to run an experiment with end-users.

Required skills
Excellent Android app development skills.

Training
Experimental design with human subjects.

References:

Pinder, C., Fleck, R., Diaz, R.L.S., Beale, R., and Hendley, R.J. Accept the Banana: Exploring Incidental Cognitive Bias Modification Techniques on Smartphones. CHI'16 Extended Abstracts, in press.

Pinder, C., Vermeulen, J., Beale, R., and Hendley, R. Exploring Nonconscious Behaviour Change Interventions on Mobile Devices. MobileHCI'15 Adjunct, ACM Press (2015).

Scott-Brown, K.C., van der Pol, M., Moncrieffe, C., et al. Service-please: an interactive healthy eating serious game application for tablet computer. BCS HCI '12, BCS (2012), 381–385.

Wiers, R.W., Eberl, C., Rinck, M., Becker, E.S., and Lindenmeyer, J. Retraining automatic action tendencies changes alcoholic patients' approach bias for alcohol and improves treatment outcome. Psychological science 22, 4 (2011), 490–7.

Project: **CS6: Augmenting human vision through subliminal cues**
Supervisors: **Prof Alan Dix (a.j.dix@bham.ac.uk)**
Charlie Pinder (c.pinder@cs.bham.ac.uk)
Bob Hendley (rjh@cs.bham.ac.uk)
Prof Russell Beale (rxb@cs.bham.ac.uk)
School: **Computer Science**

Summary: This project aims to use subliminal cues to help users to unconsciously 'see' additional information. For example, this could be used in business situations to help you remember names of people you meet. The project will use desktop displays to create prototypes of subliminal information displays and run small-scale experiments to establish the potential for this new technology.

Background and Current Technology: In science fiction, such as Iron Man, and in real world fighter cockpits, real time information is often overlaid onto the scene ahead on a heads-up display or even (in SciFi) some form of brain implant in the visual cortex. In research in augmented reality systems and visions for commercial systems such as Google glass, this information is aligned so that the overlaid display tells you about the things you see. The classic example is a bubble over each person in a meeting telling you who they are (Fig 1).

Fig 1. Augmented reality in a meeting
https://commons.wikimedia.org/wiki/
File:Konference_phone_meeting.jpg (edited)

While this would help if you are bad at remembering names, it is potentially distracting. Also those who have used heads up displays in day-to-day life report odd effects as their eyes look towards email or other displayed content, and so do not make proper eye contact with the people they are with [S00].

If images are shown only fleetingly, or are in the periphery of vision, we may not be aware that we have seen anything, but still these can have an effect [B92,R11]. For many years, subliminal images, such as these, were seen as dangerous due to the belief that they were being used for advertising; however, in recent years practical uses have been found. For example, at the University of Birmingham this kind of subliminal image has been used as part of research into behaviour change [P15].

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New Technology: The core idea of this project is use subliminal imaging in order to convey information, such as in figure 1, but without it being consciously apparent. For example, as the user looks at the person in the middle, the name 'Ted' would be displayed subliminally. The user is then expected to more easily recall the name, even though they are not consciously aware of having seen it.

Aims: The overall aim of this project is to assess whether these subliminal images can be used to convey information. This will achieved by the following objectives:

- To create a prototyping platform using subliminal imaging
- To run small experiments to test effectiveness of techniques

Methodology: The first stage will be to recreate the experiment by [D03] and then to extend it. We will create few simple examples, to get used to frame-by-frame video control to create subliminal images. This will be trialled using members of the supervisory team and/or close contacts of the intern. This first stage will establish experience in technology and also learning about experimental design and analysis. The most likely scenario will be face-name memory (as in example), with training sets and testing of prompted and unprompted recall. The second stage will be to create a tool to enable more extensive experiments; this will use a descriptor file (probably XML) with timed protocol of visible images and subliminal images. If possible this should also allow visibly played video with timed subliminal overlays. This will then be used to run more extensive experiments (ethical approval will be needed) to establish proof of concept and hopefully enough data for an initial publication.

Required skills

Computer programing including video/graphics; familiarity with statistics would be useful, but not essential

Training

Experimental design with human subjects and statistical analysis

References

[B92] Bargh, J.A. (1992). Does subliminality matter to social psychology? Awareness of the stimulus versus awareness of its influence. *Perception without awareness*. Guilford Press, New York, NY, USA, 1992, 236--255.

[D03] DeVaul, R. W., & Corey, V. R. (2003). The memory glasses: subliminal vs. overt memory support with imperfect information. In *Proceedings of the Seventh IEEE International Symposium on Wearable Computers (ISWC'03)* p. 146. IEEE.

[P15] Pinder, C., Vermeulen, J., Beale, R., and Hendley, R. (2015). Subliminal Priming of Nonconscious Goals on Smartphones. In *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct (MobileHCI '15)*. ACM, New York, NY, USA, 825-830. doi: 10.1145/2786567.2793707

[R11] Riener, A., Kempter, G., Saari, T., and Revett, K. (2011). Editorial: subliminal communication in human-computer interaction, *Advances in Human-Computer Interaction*, January 2011, p.6. doi:10.1155/2011/156028]

[S00] Sheridan, J. G., Lafond-Favieres, V. and Newstetter, W. C. (2000). Spectators at a Geek Show: An Ethnographic Inquiry into Wearable Computing, in *Proceedings of the 4th International Symposium on Wearable Computers (ISWC 2000)*, IEEE Computer Society Press, pp.195–6.

Project: **MA1: Groups and graphs**
Supervisors: **Prof Chris Parker (C.W.Parker@bham.ac.uk)**
School: **Mathematics**

The Goldschmidt amalgams determine the cubic graphs which have an edge transitive automorphism group with finite vertex stabilizers. For example, the G_3 amalgam is the amalgam $(A,B,C)=(S_4,S_4,D_8)$ and this determines the free amalgamated product $G^*=A*_CB$. The images G of G*, which are called completions, contain subgroups which we also call A, B and C (and are isomorphic to the groups in the amalgam). The coset graph $\Gamma = \Gamma(G,A,B,C)$ has vertices the right cosets of A and B in G with two cosets Ag and Bh forming an edge if and only if they have non-empty intersection and are not equal. We have that G acts edge transitively on Γ with stabilisers of vertices conjugate to either A or B. Furthermore, Γ is cubic and G acts 5-arc transitively on Γ. It has been shown in [2] that the groups $PSL_3(r^a)$ are, as long as $r^a = 4$, all completions of the G_3 amalgam. Completions of other Goldschmidt amalgams appear in various other works for example in [1]. Less has been discovered about completions of the more complicated G_5 amalgam.

In work of the supervisor, all completions of the Goldschmidt amalgams which have the property that C is a Sylow 2-subgroup of G have been determined. An easy generalisation of this work shows that the groups $G_2(r^a)$ and ${}^3D_4(r^a)$ for suitable primes r and a=1 or 2 are completions of the G_5 amalgam. These realizations give 7-dimensional representations of G^*. Since the sporadic simple groups M_{12} is completion of the G_5 amalgam and since M_{12} has a double cover it is plausible, perhaps even expected, that if we construct a double cover of the G_5 amalgam then it will have completions into groups which have a 6-dimensional projective representations over fields of finite characteristic not 2. As a guess, we would predict these groups are symplectic groups. The aim of the project is to show that the projective symplectic groups $PSp_6(r^a)$ for suitable r and a are completions of the G_5 amalgam and to investigate properties of the corresponding cosets graph. For example we would like to determine their diameter.

Here are the key steps that will be undertaken in the project:

1) Investigate the double cover of M_{12} by computer and determine a GF(3) representation of a double cover of the G_5-amalgam. By considering the entries of the corresponding matrices as elements of some extension R of the integers, try to determine a 6-dimensional representation of the double cover of the G_5 amalgam in $GL_6(R)$.
2) At this stage we will have finite images of a double cover of free amalgamated product G^* appearing as subgroups of $GL_6(R/I)$ for suitable ideals I. What do the corresponding matrices generate? We expect it is $Sp_6(R/I)$. We intend to prove this. This may need some ingenuity. One approach, for example, would be to show that the image in $GL_6(R/I)$ act irreducibly on the associated module and contains a transvection. At this stage, we may also want to borrow arguments used by Robinson in [3]. This critical step will require some extensive computational experimentation using MAGMA.
3) Write a computer program to calculate in the corresponding coset graphs and investigate the diameter of some of the smaller examples. What is the girth of the graphs calculated? Make some conjectures and attempt to prove them.
4) Write up results and produce a report.

Required skills
Familiarity with group theory and algebraic methods.

References

[1] Conder, Marston An infinite family of 5-arc-transitive cubic graphs Ars Combin. 25 (1988), A, 95-108.
[2] Parker, Christopher; Rowley, Peter Classical groups in dimension 3 as completions of the Goldschmidt G_3-amalgam. J. London Math. Soc. (2) 62 (2000), no. 3, 802-812.
[3] Robinson, Geoffrey R. Reduction mod q of fusion system amalgams.
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Project:	**PH1: Construction and characterization of a compact locking system for fibre lasers**
Supervisors:	**Dr Marisa Perea-Ortiz (m.pereaortiz@bham.ac.uk)**
School:	**Physics and Astronomy**

Cold atoms are currently being used to provide the highest precision sensors for gravity and frequency. In order to take these sensors and make useful measurements in the field (with applications ranging from underground location to financial transaction time-stamping) they have to be taken out of the laboratory and into the field. However, such an experiment typically fills a laboratory, with the optical systems used for laser cooling spreading across one or two optical tables. These free space systems are also prone to misalignment and drifts, making them inherently undesirable for operation outside of the laboratory setting. In order to take cold atom based sensors out of the laboratory, the laser system must be miniaturised and ruggedised.

One of the key constituents of such a system is the laser stabilisation system, which is used to control the frequency of the lasers used to cool and trap the atom clouds. The goal of this project would be to create an optimised packaging for a portable laser stabilisation system systems. This will teach the student involve precision alignment of components such as optical fibres and acousto-optical modulators, as well as laser stabilisation and atomic spectroscopy.

Required Skills:
Self-driven experimentalist,
Some knowledge of laser optics,
Good in aligning optics,
Carful with precision measurements,
Basic knowledge of data analysis.

Project: **PH2: Production and characterization of magnetic quadrupole trap**
Supervisors: **Dr Marisa Perea-Ortiz (m.pereaortiz@bham.ac.uk)**
School: **Physics and Astronomy**

Cold atoms are currently being used to provide the highest precision sensors for gravity and frequency. In order to take these sensors and make useful measurements in the field (with applications ranging from underground location to financial transaction time-stamping) they have to be taken out of the laboratory and into the field. However, such an experiment typically fills a laboratory and consequently can weigh several tons and consume kilowatts of power. In order to transition cold atoms from experiments and into technology, the systems must be made more compact and ruggedized.

One of the key constituents of such a system is the physics package, which is the central component responsible for both creating the clouds and providing the necessary environment. This project will focus on optimisation of the magnetic environment for cold atom systems, by implementing novel techniques for creating the required magnetic fields and removing the sensitivity to external fields. The outcome will be a more compact, power-free, lighter and robust magnetic field environment for the atoms, integrated into a working cold atom physics package.

Magnetic quadrupole traps (MQT) are commonly used in cold atom physics for its simplicity on building and linear features. Usually the MQT is generated by a pair of identical coils in anti-Helmholtz configuration. Also MQT are a fundamental part to produce Magneto Optical Tap (MOT). MOT is the primary stage for cooling atoms therefore improving and studying MQT would be useful.

This project aims to create different sets of MQT using different configurations and dimension of coils. Other potential line of study is the use of permanent magnets to create the MQT. Permanent magnet would bring the advantage of reducing the power consumption on the MOT. And hopefully also reduce the size of the MQT.
Characterization of the magnetic field and gradient produced by the MQT is expected be done during the project. This includes experimentally measurements and maybe if the time is enough simulations.

Required Skills:
Self-driven experimentalist,
Good in manual work,
Carful with precision measurements,
Basic knowledge of data analysis

Project: **PH3: Narrow-band light from nonlinear optics in a fibre ring resonator**
Supervisor: **Dr Jon Goldwin (j.m.goldwin@bham.ac.uk)**
School: **Astronomy and Physics**

Optical resonators are used extensively in experiments with ultracold atoms, either as optical spectrum analysers or to create high intensity fields from relatively weak sources. The most familiar cavity construction is arguably the Fabry-Perot etalon formed from a pair of mirrors. For this project you will study a ring resonator formed from a loop of single-mode optical fibre. Besides being rugged and compact, the optical fibre ring resonator will allow you to access nonlinear optics at relatively low intensity. In this regime the dominant optical nonlinearity in optical fibres is stimulated Brillouin scattering (SBS), which involves four-wave mixing between three optical fields and propagating phonons in the fibre core. This produces a back-scattered "Stokes" wave from an incident pump beam. Although SBS is a thorn in the sides of engineers wishing to send high optical powers through long lengths of fibres, this Stokes wave is predicted to undergo significant gain narrowing and exhibit a spectral purity which is orders of magnitude better than that of the pump laser. This makes the SBS oscillator a potentially useful tool for generating ultra-coherent light sources over a wide range of wavelengths.

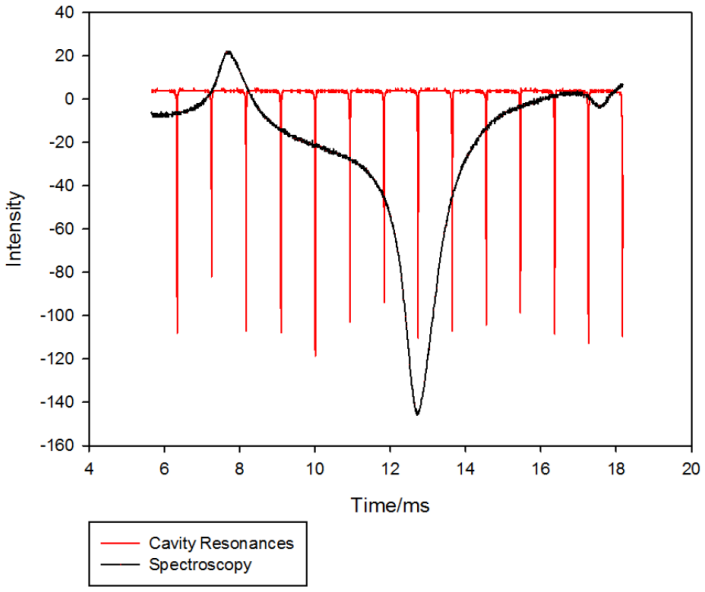

Figure 1: fibre ring transmission resonances (red) and Doppler-free absorption resonances in potassium (black). The laser frequency is scanned in time, with the dominant atomic peak and valley separated by 230 MHz.

You will study SBS in a fibre ring resonator near the strong laser cooling transitions of rubidium (780 nm). After characterising the gain and spectral properties of the Stokes wave, the SBS oscillator frequency will be stabilised to an atomic absorption resonance to provide long-term stability. This project has applications in our experiments in quantum metrology and coherent light-matter interactions, and may lead to next-generation superluminal ring laser gyroscopes.

Project: **PH4: Nanoscale Physics (multiple studentships)**
Supervisor: **Prof Richard Palmer (r.e.palmer@bham.ac.uk)**
School: **Astronomy and Physics**

Up to 6 places are available for summer projects in the Nanoscale Physics Research Lab. Students will be fully integrated into the research group and will share an office with other researchers for the duration of the project. The projects represent an invaluable experience, especially for excellent students considering a PhD in nanophysics or a related discipline; many previous project students have gone on to PhDs in Birmingham and other leading Universities. The experiments are always difficult so the highest level of capability and motivation is essential. The typical project duration is 8 weeks, start date to be agreed but usually late June.

We expect to offer places in the areas of: (i) atomic manipulation with the STM, (ii) atomic-resolution electron microscopy of nanostructures, (iii) super-abundant generation of nanocluster materials for photonics and electronics and (iv) nanowire production, *plus* up to two places in nanobiosensors, in collaboration with one of our spin-off companies.

An example of a possible project is below:

Remote control of atomic manipulation
Atomic manipulation is the extreme limit of nanotechnology [1]. The Scanning Tunnelling Microscope (STM) is employed both to manipulate individual atoms or molecules on surfaces - either by the application of mechanical forces or by the injection of electrons or holes - and to images the results with atomic precision. We are especially interested in non-adiabatic processes in which capture of an electron (or hole) from the STM tip suddenly projects the atom/molecule onto an excited quantum state potential surface which drives the dynamics until charge release. Recently [2] we discovered that electrons can be injected far away from the location of the target molecule, propagating across the surface in quantised surface electronic states, thus uniting (in principle) device physics with atomic manipulation (hence 'remote control'). The work was published in Phys Rev Letters and highlighted in New Scientist. This project will investigate the possibility of channelling the electrons in 2D along waveguides created by atomic manipulation on the Silicon (111) surface, along which electrons will be launched to drive atomic manipulation (cf. switching) events in pre-positioned chlorobenzene molecules. The experiments should also allow us to test our sub-surface electron transport ('submarine [2]) hypothesis. We think that, ultimately, similar ideas can in principle be applied to biological molecules (proteins), where there is the possibility to achieve bond-specific surgery on individual molecules (in a liquid environment).

References:
[1]. Two-electron dissociation of single molecules by atomic manipulation at room temperature, P.A. Sloan and R.E. Palmer, Nature 434 367 (2005).
[2]. Nonlocal desorption of chlorobenzene molecules from the Si(111)-7x7 surface by charge injection from the tip of a scanning tunneling microscope: Remote control of atomic manipulation, P.A. Sloan, S. Sakulsermsuk and R.E. Palmer. Phys. Rev. Lett. 105 048301 (2010); *see also* Electron 'submarines' help push atoms around, *E.S. Reich,* New Scientist, 31 July 2010, p. 11.